Correlations Between Heart Failure, Age, Arterial Compliance, and Other Biomarkers: Found Using Machine Learning Algorithms

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Introduction

Medical Flow Physics Laboratory

USC’s Medical Flow Physics Laboratory (MFPL), led by Dr. Pahlevan, uses machine learning, physics, mathematics, and experimental setups to study cardiovascular mechanics. Their projects range from finding relationships between heart failure and brain injury, to inventing non-invasive monitoring devices (such as smartphone applications) for pediatric patients and cardiovascular diagnoses. Additionally, they frequently use machine learning and artificial intelligence to find accessible interventions for heart failure patients, through finding correlations between cardiac biomarkers and cardiovascular diseases. Their projects have the potential in both clinical and diagnostic applications.

Application

Heart diseases are the <u>leading cause of death</u> in the U.S., with one in five Americans dying, from this cause alone, annually. Purpose of this study is to forcast heart failure by finding correlations between arterial compliance and other biomarkers in affected participants’ data. This analysis was done using machine learning algorithms. Arterial compliance is defined as the change in arterial blood volume due to a given change in arterial blood pressure ($\Delta V/\Delta P$). It lowers with age, and can be used, along with other biomarkers, to improve prognosis of susceptible patients.

Artificial Organ Fabrication

The artificial organ fabrication process consists of coating metal aorta molds with silicone or latex, and hanging them to dry. After multiple coatings, water is injected between the mold and the material to detach the aorta, and the branches are removed. The latex aorta requires bleach treatment so that it maintains its structural integrity when attached to the aortic setup. For left atrium and left ventricle fabrication, a water-soluble mold is 3D printed, brushed with silicone, and dissolved in water.

Machine Learning Algorithms

Selection of Model Parameters

- Patient participant heart failure data from the Framingham Heart Study (6698 participants, female and male, from ages 19 to 90, this model used 48 data points)
- All models programmed in Python
- Correlations found between biomarkers using a heat map
  - Absolute value of darkest and lightest squares less than 0.85 were selected (highly correlated but not overfit)
  - Output: Compliance; Inputs: Age and three Intrinsic Frequency (IF) parameters (noted as 'W2_bar', 'W2N', and 'W2C')

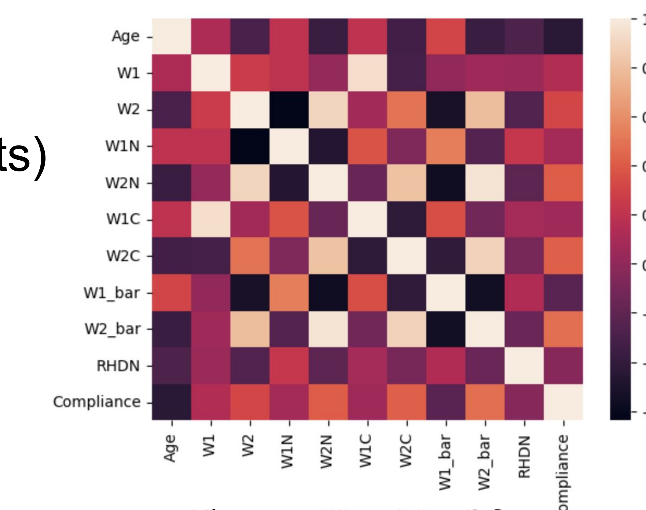


Figure 1: *Heat Map PC: Melodie Ebrahimi*

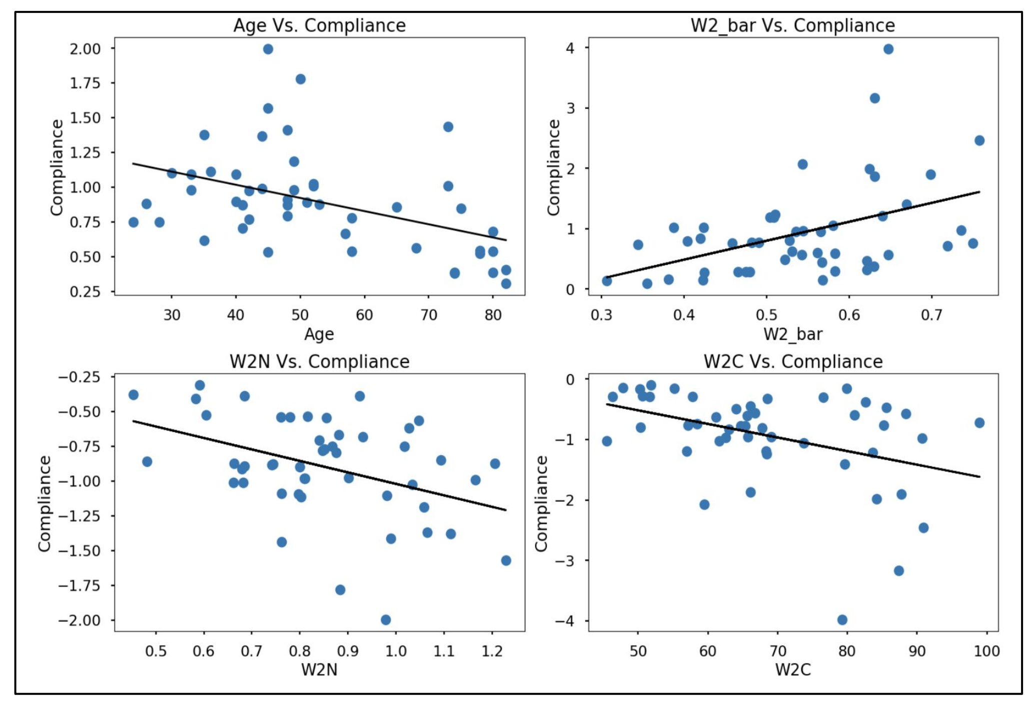


Figure 2: *Subplot of Compliance and Other Biomarker Correlations (Data from the FHS-Cohort) PC: Melodie Ebrahimi*

Linear Regression Model

- Supervised model: best linear fit between independent and dependent variables

Random Forest Model and Decision Tree Model

- Averages multiple decision trees, less noise sensitive
- Hierarchical, tree structure: root node, branches

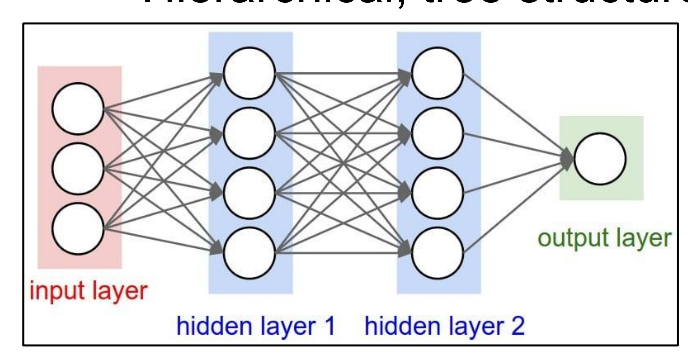


Figure 3: *Deep Neural Networks “What’s a Deep Neural Network? Deep Nets Explained” by Jonathan Johnson*

Deep Neural Networks (DNN) TensorFlow Model

- Complex neural network
- Mimics the brain
- Hidden layers allow learning and categorization of output

Methods and Results

Machine Learning: Iterative Process and Results

- By iterating through different model parameters, and trying many algorithms, I found the Decision Tree model to yield the highest Pearson correlation coefficient (R value) of approximately $\boxed{0.82,}$ which is a high valuation

Aortic Compliance Data Collection

- Collected latex and silicone aorta compliance data using a pressure catheter (Millar MIKRO-TIP®)
- The silicone aorta had an average compliance of .75 mL/mmHg, which corresponds to an age of 83

Figure 4: *Hanging Aortas PC: Melodie Ebrahimi*

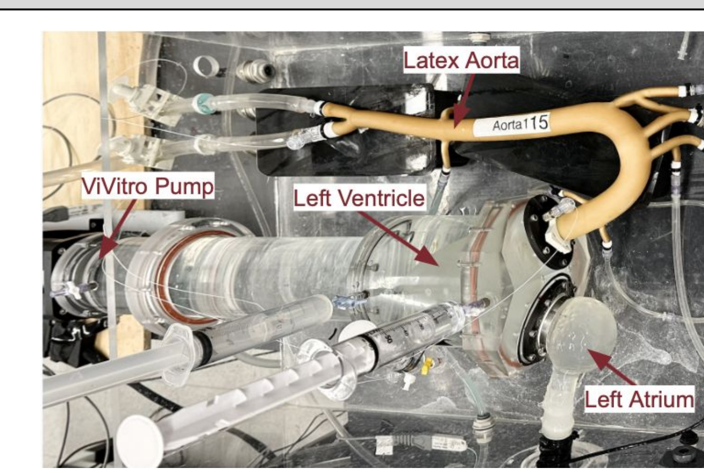


Figure 5: *Coupled Atrioventricular-aortic Setup PC: Coskun Bilgi*

Figure 6: *Latex Aorta Ascending Pressure PC: Melodie Ebrahimi*

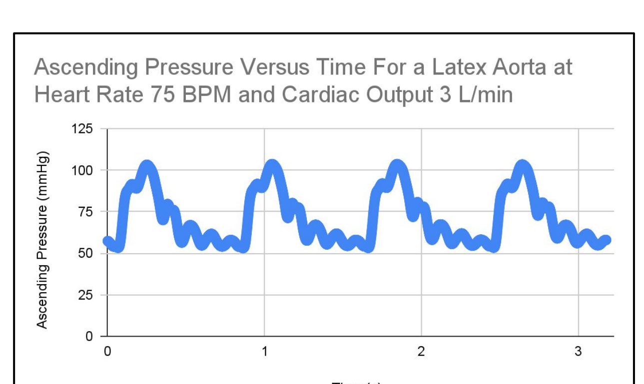
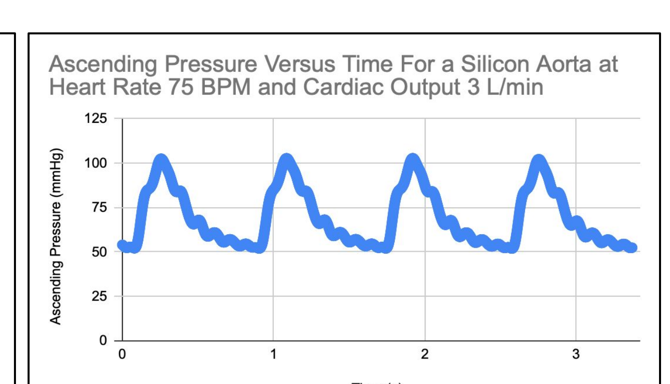


Figure 7: *Silicone Aorta Ascending Pressure PC: Melodie Ebrahimi*



- The latex aorta had an average compliance of 0.94 mL/mmHg, which corresponds to an age of 45
- Neither of these aortas were intended to have Heart Failure when fabricated (consistent when compared with machine learning data)

Coupled Atrioventricular-aortic Setup: Aortic Pressure Data Collection

- Ascending pressure of the latex and silicone aortas were compared: waveforms have slight differences

Discussion

Project Limitations

The R value for the DNN was the lowest of all models tested. This may be due to the small patient data sample (n=48) used.

Future Directions

Using clinical trial data collected at MFPL to predict other cardiovascular diseases. Continued compliance data collection by fabricating patient specific diseased aortas. Improving patient prognosis: smartphone app for prevention that compares participant values to previously affected patients’ data.

Figure 8: *Smartphone Cardiac Measurement App PC: MFPL*

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